**FINAL REPORT**

SURVEYS AND INVESTIGATIONS PROJECTS

As Required By

FEDERAL AID IN WILDLIFE RESTORATION ACT

MISSOURI

**FEDERAL AID PROJECT NO. W-13-R-41 (1987)**

STUDY NO. 85: **Avian Habitat Relationships and Wildlife Management Planning in Missouri**

Job No. 1: Avian habitat relationships and wildlife management planning in Missouri

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FINAL REPORT

SURVEYS AND INVESTIGATIONS PROJECTS

STATE OF MISSOURI

Project No. W-13-R-41 (1987) | Study No. 85 | Job No. 1

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## ABSTRACT


We chose to initiate this project with a pilot study. We used data collected earlier in a study of avian response to wildlife management, and collected a new set of data on ovenbird (Seiurus aurocapillus) and Kentucky warbler (Oporornis formosus) territories and nests. Two statistical techniques were chosen for investigation--principle component analysis (PCA) and logistic regression.

We sampled vegetation within 16 ovenbird and 23 Kentucky warbler territories, and at 43 random sites on the Ashland Wildlife Research Area. These were analyzed along with information on 41 habitat variables collected on 21 sample sites in the earlier study.

We found the results of PCA and logistic regression analysis to be useful in evaluating species-habitat relationships on an exploratory level. We also believe that the graphical display of PCA analysis will prove useful to wildlife managers for visualizing habitats selected by particular species.

These techniques, however, are data hungry. Our sample sizes were not adequate for all of the analyses that we would like to have performed. We propose that this line of research be continued in two ways. First, these data sets, along with similar data collected in yet a third study, should be used to formulate models of avian-habitat relationships suitable for testing in the field. Second, we should design and conduct additional studies of other species, with increased sample sizes and improved precision of habitat variables.

FINAL REPORT

SURVEYS AND INVESTIGATIONS PROJECTS

STATE OF MISSOURI

**Project No. W-13-R-41 (1987)** **Study No. 85** **Job No. 1**

Study No. 85: Avian Habitat Relationships and Wildlife Management Planning in Missouri

Job No. 1: Avian habitat relationships and wildlife management planning in Missouri

Objectives:

To identify measurable habitat parameters that are highly correlated with the distribution and abundance of birds in central Missouri; to evaluate the feasibility of an expanded study designed to test the underlying assumptions of modeling systems currently used in wildlife and habitat management planning in Missouri.

Introduction:

The Missouri Department of Conservation (MDC) has been involved either directly or indirectly in management for nongame wildlife since its inception in 1936. Inadequate or inappropriate funding sources, however, precluded the implementation of large-scale programs. This recognized need, among others, was of primary importance in the creation of the "Design for Conservation" in 1976 (Noren 1978).

The Design for Conservation identified land acquisition for primary emphasis during the early phase of this program. Also identified were expanded management and research activities, especially those directed at nongame and endangered species (Missouri Dept. of Conserv. 1975).

The Wildlife Division of MDC conducted a "Program Review" in 1982 (Murphy 1982). It placed a high priority on the management, preservation, and restoration of all wildlife resources on Division lands. Program Review also highlighted the Division's responsibility to provide a wide range of wildlife-related public recreation.

As MDC's land acquisition goals are being met, the emphasis of the Department's program is shifting to development and management of these lands. Careful and comprehensive planning will be necessary to provide for the diverse needs of the wildlife resources of Missouri. Key elements of the planning process should include: (1) techniques with which to inventory lands, land-uses, vegetation, and wildlife, and (2) a process with which to integrate the information collected in the inventory and select from among the various management options available. Fundamental to both of these elements is the identification of key, measurable parameters that influence the distribution and abundance of selected wildlife. Without this basic information, an efficient, effective system of comprehensive wildlife management planning will not be possible.

The U.S. Forest Service, Mark Twain National Forest (MTNF) and MDC both have used species modeling to some degree in their management planning. MTNF has adopted the Pattern Recognition (PATREC) modeling system (Williams et al. 1978), while MDC has used both Habitat Suitability Indices (HSI) (Urich et al. 1984) and PATREC. These models use the condition of key habitat parameters to predict animal population levels. The models thus far have been constructed from available literature sources and expert opinion, rather than from extensive field testing and evaluation. This represents an adequate start, but testing of the underlying assumptions of the models is essential to make it a viable process.

Assessing the habitat requirements of a species can be a difficult task for a wildlife biologist. The high number of potential habitat characteristics to be considered and measured, as well as the variety of habitat patterns that the biologist would need to test in order to determine which characteristics in which combination are necessary for the survival of a species, create a bewildering array of possibilities for study. Yet a wildlife manager needs to know all of these if he/she wishes to ensure that a species will occur on a particular piece of land. Though faced with the enormity of this problem, ecologists and wildlife biologists have attempted to tackle it (Verner et al. 1986).

The structure of data normally used for an evaluation of this kind consists of measured habitat parameters and species occurrence or abundance. The typical scenario for collecting these data is as follows:

The biologist determines which species is desirable for study. A literature search for information about its habitat requirements, as determined by previous researchers, is conducted. Given this information base and the biologist's own biases about the habitat needs of the species, a list of habitat characteristics to be measured is selected. Normally, this list is extensive (more than 30 characteristics). Sample sites then are selected for study. Given the difficulty of measuring the habitat characteristics and the usual budgetary constraints, normally only a few sites (less than 100) are chosen. It then is off to the field to collect the data. After the field work is completed, it is time to analyze the collected data. The results from these analyses then are added to the body of knowledge about this species and its habitat.

The weakest link in this scenario typically is the analysis phase. The number of statistical options that are available at this point are as numerous

as habitat characteristics. Most of the recommended choices are from the family of multivariate statistical techniques (Pielou 1984, Poole 1974, Gauch 1982). This family of statistics allows examination of the multidimensional nature of wildlife habitat. A number of techniques, such as canonical correlation, factor analysis, discriminate function analysis, cluster analysis, principle component analysis, and multivariate analysis of variance can be used. Capen (1981) reviewed several of these as they apply to wildlife habitat evaluation. A problem with these techniques is the difficulty of directly applying the complex interpretation of their results to management situations.

We chose to initiate this project with a pilot study. We have available data collected in a study of avian responses to wildlife management at 4 wildlife management areas in central Missouri (Callaway, Cooper, and Randolph counties) (Clawson 1981). We also collected data on ovenbird (Seiurus aurocapillus) and Kentucky warbler (Oporornis formosus) territories and nests at the Ashland Wildlife Research Area (AWRA) in Boone County during Summer 1984. The purpose of this pilot study was to further investigate the analysis of species-habitat relationship data to develop an analytical approach for future habitat studies that would directly aid wildlife managers in Missouri.

Two statistical techniques were chosen for investigation--principle component analysis (PCA) and logistic regression. These two techniques were especially attractive given the limits that we placed on the data for this study. First, species information was restricted to presence/absence data for each sample site. Second, habitat characteristics consisted of mean values from selected plots within each sample site.

PCA was used to transform the original set of habitat characteristics into a set of linear combinations. This set of combinations usually is smaller than the number of variables (habitat characteristics measured) and

accounts for most of the variation of the original set. The purpose of PCA is to determine principle components in order to explain as much of the total variation in the data as possible with as few of these components as possible (Dillon and Goldstein 1984).

We chose PCA because sample site information could be plotted graphically for each component. This has the advantage of visually depicting those sample sites where a species was present in relation to all other sample sites on a reduced dimensional scale (see Figure 1).

Rotenberry and Wiens (1981) used a more complex approach of combining species habitat patterns with sample site information to display species-habitat relationships. Our approach was simpler because we used only the first two principle components from the sample site mean habitat patterns to highlight those sites where a species was found. The reason for using only two principle components was the ease of interpretation in two dimensional space (graphical form). We felt that if wildlife managers had an idea of the habitat characteristics of each selected sample site, they would be able to visualize the kinds of areas in which a species exists. They therefore could manage their area so that it would fall within the grouping of habitat characteristics that the species selected.

Logistic regression was chosen because of its unique capability to use presence/absence or success/failure information as a dependent variable in regression. The independent variables in logistic regression may consist of either discrete or continuous data (Cox 1970). Independent variables can be selected in a stepwise approach similar to linear regression (Draper and Smith 1966), or variables can be tested to determine if they have significant slopes (beta values) when all variables are included in the model. This approach is similar to one developed by Smith and Connors (1986).

Techniques Used:

## METHODS

Ovenbird and Kentucky warbler territories were delineated using the Breeding Bird Census technique (Robbins 1970). The 5 compartments of the AWRA were surveyed at least 5 times during the breeding period, late May-June. In the early morning (dawn until approximately 9:30 AM CDT), the observer walked slowly through one-half of a compartment, usually following topographic contours, and pausing frequently to note the locations and behavior of birds. Birds were plotted on maps of the compartments. After the early morning surveys were completed a composite map was prepared for each compartment. Clustering of observations indicated the presence and location of territories.

The vegetation on the study area was sampled following the method of James and Shugart (1970). Circular plots 0.04 ha in size were placed: (1) randomly within identified territories (5 plots per territory), (2) at nest locations discovered during the course of our census and survey work, and (3) at random locations throughout AWRA. After a plot center was marked with flagging, two 22.6 m lines running North-South and East-West were established, thus dissecting the plot into quarters. The observer walked these lines taking 20 equally-spaced measurements (10 per line) of each of the following: canopy and subcanopy closure (by sighting through an ocular tube); ground cover and height (by blindly placing a meter stick at arm's length to one side and recording the type and height of the tallest living vegetation touching the stick; and litter cover and depth (with the meter stick, noting the height of the tallest piece of vegetation from the previous year's growth that touched the stick). The number of woody stems taller than 1 m and less than 2.5 cm diameter at breast height (dbh) was determined by walking the lines and counting all stems within 1 m either side of a line (a subsample of 0.008 ha).

All living and dead trees greater than 2.5 cm dbh were measured with a Biltmore stick and recorded by size class (10 classes in total). The percent ground cover in grass, forbs, and woody types was estimated ocularly. The maximum canopy height was estimated using a Biltmore stick. And slope and aspect were noted for each vegetation plot.

Both the avian and the vegetation sampling methods were as above in the avian response to wildlife management study, with the following 2 exceptions: all birds and their behavior were recorded, and vegetation plots were placed randomly on sample sites, rather than within known bird territories (for details see Clawson 1981).

The SAS statistical package (SAS Institute Inc. 1985) was used for both PCA and logistic regression (SAS Institute Inc. 1983) during data analysis. Within logistic regression a probability level of 0.10 was used to determine significance.

## STUDY AREAS

The AWRA comprises 923 ha owned and managed by the University of Missouri, Columbia and the Missouri Agricultural Experiment Station (Fig. 2). It lies approximately 24 km south of Columbia in Boone County, Missouri. The AWRA lies within the Ozark Border physiographic division of Missouri (Thom and Wilson 1980). Cover types present on the AWRA include:

Oak-hickory forest..................65%

Eastern red cedar...................23%

Bottomland hardwoods................ 3%

Pine plantations.................... 2%

Old fields and food plots........... 6%

Buildings and experimental areas..... 1%

The area is divided into 5 compartments for management and research purposes.

For a description of the avian response to wildlife management study sample sites, see Clawson (1981).

Findings and Analysis:

We located a total of 36 ovenbird and 34 Kentucky warbler territories on the AWRA (Table 1). It was difficult to find nests of both species, but it was especially so for ovenbirds. We found 10 Kentucky warbler nests and only 4 ovenbird nests (Table 1).

We sampled vegetation within 16 ovenbird territories and 23 Kentucky warbler territories (Table 2). We sampled the vegetation around each nest and at 43 sites located randomly on the AWRA (Table 2).

## PRINCIPLE COMPONENT ANALYSIS

### 1981 Study

Information on 41 habitat variables was collected on 21 sample sites during the summer of 1979 (Clawson 1981). The mean values of these variables taken on 10 randomly selected plots on each sample site were used in the PCA. Because there were more variables than sample sites, procedures developed by Jolliffe (1972, 1973) were used to discard variables that added little to the resulting PCA. The average-linkage method of hierarchial cluster analysis was used in this step as recommended by Seber (1984, page 200). We used the NTSYS computer program (Rohlf et al. 1972) to reduce the number of habitat variables to nine. Because there are two possible choices at each inner linkage less than 0.45, we selected two sets of variables to test (Table 3). Using the correlation matrix of habitat variables in PCA, the two sets of chosen

variables give slightly different graphical representations of the data (Figure 3). Figure 3A shows a larger separation on the first principle component between those areas classified as "closed" and those classified as "open" (Clawson 1981) than does Figure 3B. More than 63% of the cumulative total variance was accounted for by the first two principle components shown in Figure 3A, and 60% in Figure 3B (Table 4).

We chose to examine the avian species information for the summer of 1979 based on the results of the data displayed in Figure 3A. The species we selected were mourning dove (Zenaida macroura), blue grosbeak (Guiraca caerulea), blue jay (Cyanocitta cristata), cardinal (Cardinalis cardinalis), wood thrush (Hylocichla mustelina), and eastern wood pewee (Contopus virens). These species represent 2 "grassland" birds, 2 "woodland" birds, and 2 "generalists". The PCA plots for these species are shown in Figure 4. Each species fits this data very well. The grassland species were found to occupy those areas within the "open" group, and the forest species occupied those in the "closed" group. The generalists occupied both "open" and "closed" areas. It should be noted that there appears to be an outlier in the "closed" group for mourning dove, and one in the "open" group for eastern wood pewee. The mourning dove outlier occurred because there was a pond in the corner of one of the forest study sites. Around the pond were several standing dead trees that were used as song posts by mourning doves. The eastern wood pewee outlier occurred because two of the edges of a grassland study site were bordered by cedar (Juniperus virginiana) and shrub-tree fenceline that provided foraging perches for the pewee. This shows the importance of knowing what other habitat characteristics on a sample site may affect bird occurrence, even though they were not measured, and serves as a warning to be cautious in interpreting the results from PCA.

AWRA Study

Habitat characteristics for 29 variables were used in the PCA from the ovenbird-Kentucky warbler study. The mean habitat values for individual bird territories were used in the analysis. The habitat values for the random plots were used as recorded in the field, unless the plot had more than one sample taken. When a random site had been sampled several times the mean habitat values were used; this occurred 5 times. Thus, in our analysis we used 23 Kentucky warbler sites, 16 ovenbird sites, and 23 random sites (for a total of 62 sample sites) for PCA. Discarding variables was not necessary for these data.

Figure 5 shows the results of the PCA when all 62 sample sites were used. Nearly 29% of the cumulative total variance was accounted for by the first two principle components (Table 5). Because ovenbirds and Kentucky warblers both are "forest interior" species and all sites were located within forested areas, these results appear reasonable. Ovenbird sites cover a smaller range of values than do Kentucky warbler sites.

We also analyzed ovenbirds and Kentucky warblers separately with the random sites (Figure 6). These analyses show results almost identical to the combined information. Again, nearly 29% of the cumulative total variance was accounted for by the first two principle components in both analyses (Table 6). The variables within each principle component played a different role in these two analyses, however. For example, with ovenbirds percent subcanopy cover had the most influence on the first principle component, while percent canopy cover had the most for Kentucky warblers. A number of variables also had sign changes (see Table 6).

Nest locations for ovenbirds and Kentucky warblers were analyzed using PCA. Four ovenbird and 10 Kentucky warbler nests were found and habitat

characteristics were measured at these locations. These habitat values at the nest site, the mean habitat values for the remaining territorial area, and the random site values all were used in the PCA (71 sample sites in total). The results depicted in Figure 7 show that Kentucky warbler nest sites fall within the range of habitat characteristics selected as habitat for their territories, and do not appear to be unique from the habitat surrounding them. We did not find enough ovenbird nests to make an adequate comparison with the habitat selected for their territories, therefore our analysis should be considered tentative.

## LOGISTIC REGRESSION

### 1981 Study

Due to the small sample size (21 sample sites) and the large number of variables (41 habitat characteristics), logistic regression was not very helpful. For the purpose of illustration, however, we will show the results of logistic regression analysis for the 6 species (mourning dove, blue grosbeak, blue jay, cardinal, eastern wood pewee, and wood thrush) demonstrated for PCA.

Table 7 shows the results of the logistic regression analysis for the six species. For mourning dove there were two significant equations. One included the size of the area (SIZE2), and the other had to do with crops on the area (CROP2). When both variables were included in the logistic regression equation, however, the SAS procedure (PROC LOGIST) (SAS Institute Inc. 1983, page 181) failed in the estimation of the model. For both CROP2 and SIZE2, the probability of finding mourning dove present on an area increased as the value for these parameters increased.

The logistic regression equation for blue grosbeak included the mean litter depth variable (MLH) (Table 7), because higher MLH values were associated with grasslands and cropfields, as opposed to the woodland study sites that had only leafy materials making up the litter component.

For the two generalist species--blue jay and cardinal--significant equations were found. The probability of finding a blue jay present on a sample site decreased as the proportion for the area covered by grass (MGRASS) increased, and the probability of finding a cardinal increased with SIZE2 (Table 7). Neither of these results was unexpected. Blue jays tend to be associated more with woods and woodland edges than with large grasslands. And, as the size of an area increases in Missouri, so does the probability of encountering an edge containing a cardinal.

Logistic regression analysis showed that the probability of finding an eastern wood pewee decreased as the proportion of litter cover (MLIT) increased (Table 7). MLIT increases in a grassland environment where eastern wood pewees normally are not found.

For wood thrush, no significant models were found because PROC LOGIST failed in the calculation of the beta values for habitat characteristics associated with size class 3 for living trees (MLIVE3) and size class 2 for dead trees (MDEAD2) (Table 7). These two variables may be associated with the probability of wood thrush presence because wood thrushes frequently are found in rich, mesic sites that have high sapling stem densities.

AWRA Study

Logistic regression was used to examine two different relationships between Kentucky warbler and ovenbird habitat characteristics. The first relationship consisted of the probability of the bird being present based on habitat characteristics. The other relationship examined the probability of a nest being present as predicted by habitat variables.

The model for predicting whether or not a Kentucky warbler would be present on a sample site consisted of four habitat characteristics (Table 8). Mean ground cover (MGRDCV), mean number of woody stems (MWDYS), mean litter depth (MMLTRDP), and mean number of class 3 live trees (MCL3) all were significant variables in the model. Kentucky warblers need an area that contains low shrubby or woody cover, and these may be associated with areas containing small saplings and an accumulation of leaf litter. For the ovenbird, only MMLTRDP was a significant variable in the model (Table 8). This may be because ovenbirds need an area with sufficient litter accumulation to provide a site for placement of their ground nests.

Significant models for predicting the presence of a nest for both Kentucky warbler and ovenbird were found. Two variables were significant in the Kentucky warbler nest model: mean maximum canopy height (MXCANHT) and MGRDCV. These may indicate that Kentucky warblers select nest sites in mature forest that has a good low cover component, as above. The model for ovenbird nests identified mean number of class 5 dead trees (MCD5) as a significant variable. We do not have a good explanation for this, except to speculate that, due to small sample size, this may be a spurious correlation.

## Discussion and Recommendations:

We believe that principle component analysis and logistic regression are valuable tools in evaluating species-habitat relationships on an exploratory level. PCA and logistic regression allow one to examine possible relationships between sets of habitat variables and species occurrence. The general assumption of both techniques, as we used them in this study, is that the response variable (species occurrence) is binary in nature. We did not attempt to evaluate population size or response to habitat characteristics on our sample sites other than by presence or absence on the area.

PCA has been used by other researchers to aid in the description of species-habitat relationships. For example, Conner and Adkisson (1977) used PCA to evaluate habitat relationships for 5 woodpecker species. Their goal was to determine habitat characteristics that these woodpecker species preferred. They found agreement between their results and those of other researchers of woodpeckers. Likewise, we found agreement with our results from PCA and what we have observed in the field (other than on our sample sites).

Unlike Conner and Adkisson (1977), however, we did not attempt to explain the principle components given habitat characteristics. We simply displayed the species occurrence by sample plot on the first two principle components in graphic form. We believe that this approach will be less confusing to wildlife managers than explanations about individual habitat characteristics. Detailed statistical interpretations may not have any biological meaning, even when they are fully understood.

Logistic regression has not been used extensively in the study of species-habitat relationships. Smith and Connors (1986) used this technique to examine shorebird species and habitat characteristics along the Alaska coast near Point Barrow. They found several habitat variables that appeared to correlate quite well in their species occurrence models. Brennan et al. (1986) also used a number of techniques including logistic regression to determine variables for HSI's. They felt that logistic regression worked somewhat better than other multivariate techniques they tried. Our experiences with logistic regression for determining habitat variables that appear to be related to species occurrence concur with these researchers. We believe that logistic regression has a place in examining species-habitat relationships under the proper study design.

One difficulty in our approach to these statistical techniques during this pilot study was low sample size. Both techniques, as we used them, are "data hungry," requiring a large number of sample sites over a broad range of conditions. For these techniques to be useful, this broader sampling strategy would be necessary. This would be rather expensive and require more resources. Even if the funding and resources were available, however, we still would be faced with the fact that these types of studies are exploratory in nature and not confirmatory (Noon 1986).

Thus, we find ourselves at the third phase of Noon's (1986) modeling process. We have posed our initial question: What parameters determine the occurrence and abundance of birds on wildlife management areas? We have collected a series of observations and explored them using multivariate analyses to search for patterns in the data. We now can build empirical models based on the data gathered in our observational work, test the predictions of these models with additional observational data, and, if necessary, refine the models. The ultimate test of a model, of course, would be to manipulate the parameters identified as significant to the species in question in a cause-and-effect experiment to determine whether or not, and to what extent, the species actually responds (James and McCulloch 1985, White and Garrott 1987).

We recommend that this line of research continue with: (1) further analysis of these data sets, along with similar data collected in another study, to formulate models of avian-habitat relationships suitable for testing in the field, and (2) studies of other species, with increased sample sizes and precision of habitat variables.

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Data and Reports:

Original data and related reports in this investigation are on file in the Federal Aid Office of the Missouri Department of Conservation, Columbia, MO 65201.

Figure 1. An example of a graphical representation of the first 2 components of PCA. Pluses depict the distribution of sample sites; diamonds depict the distribution of a grassland bird. The line connecting the diamonds highlights those sample sites where the species occurred.

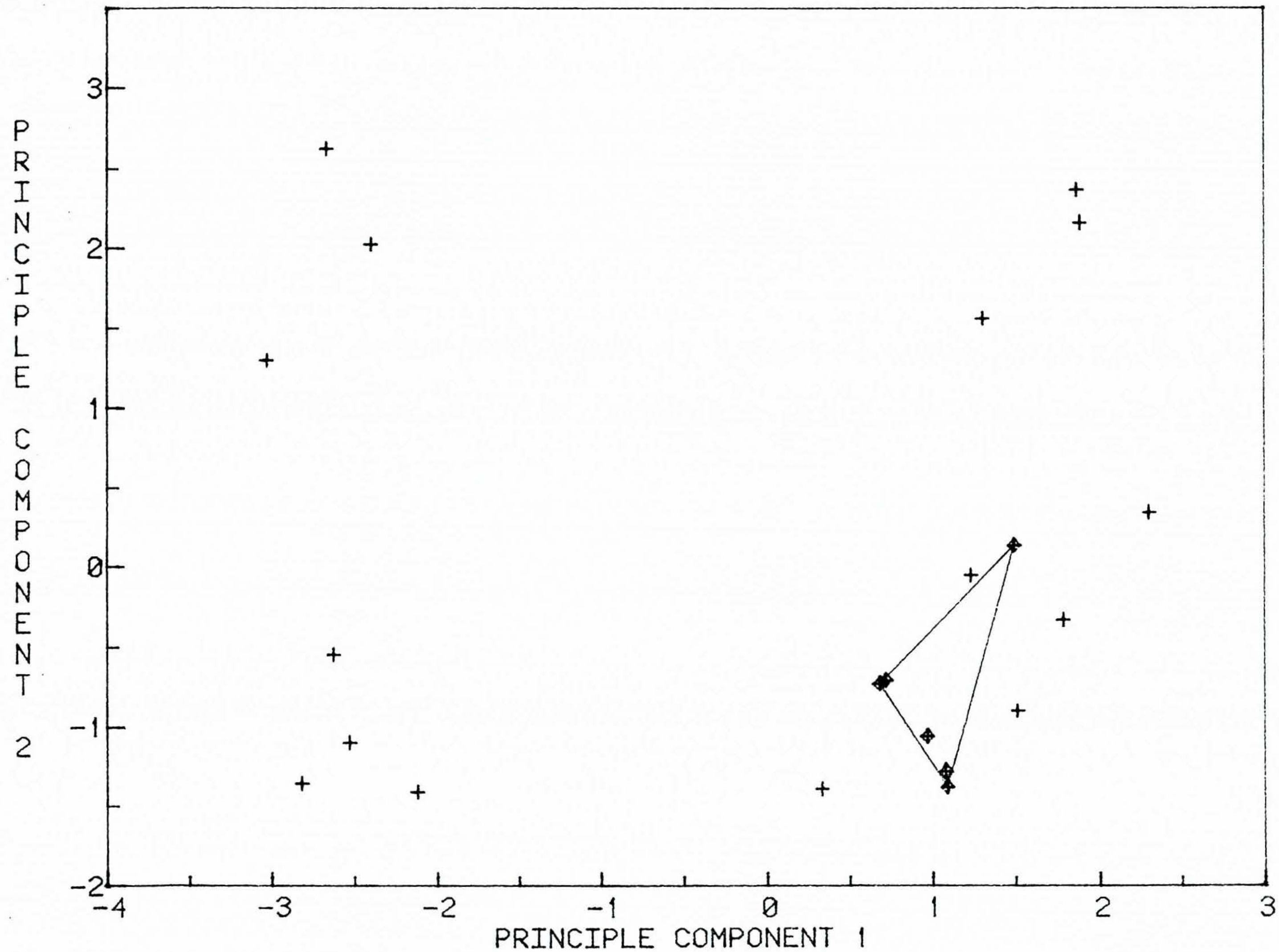


Figure 2. The Ashland Wildlife Research Area.

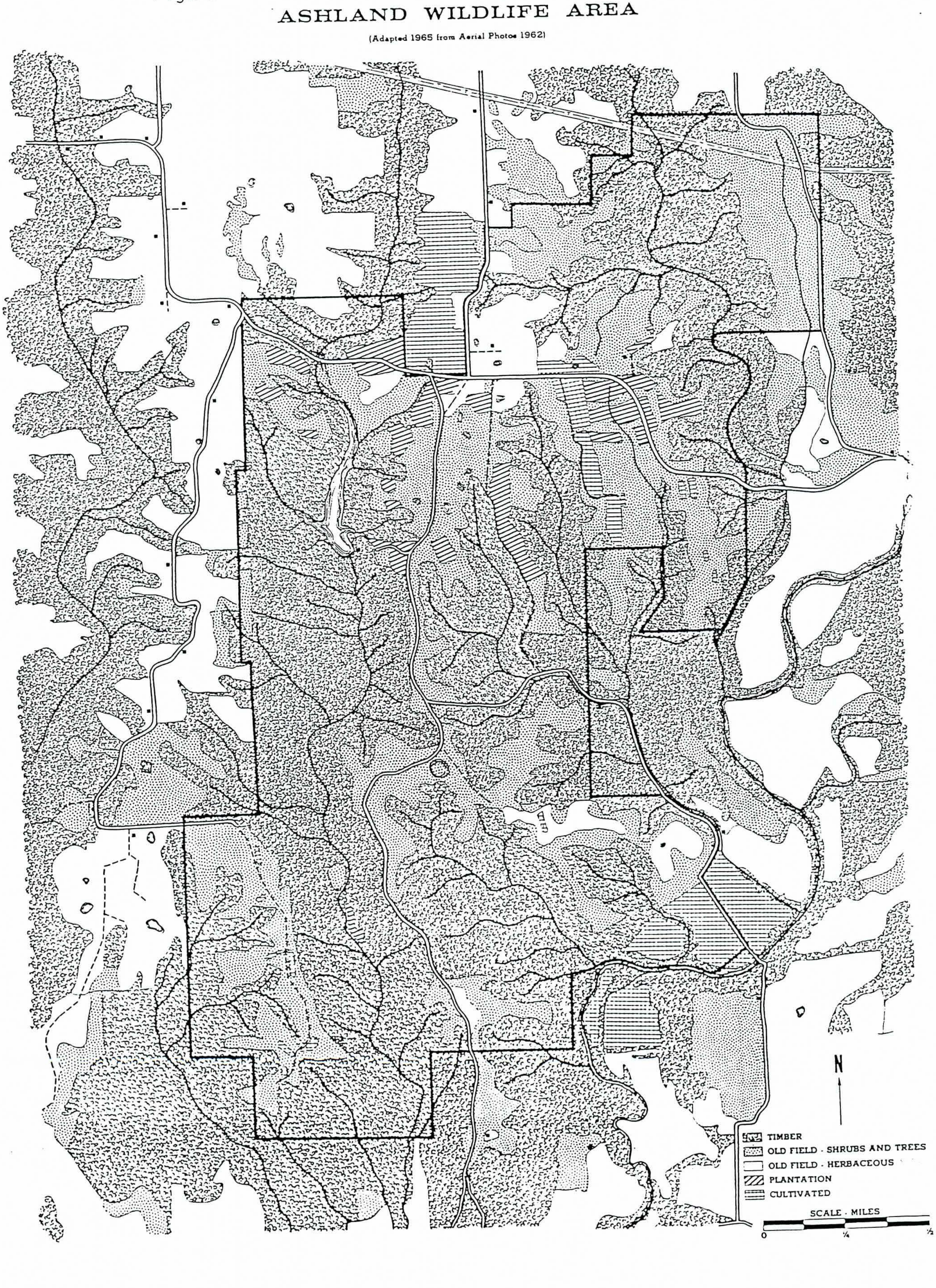
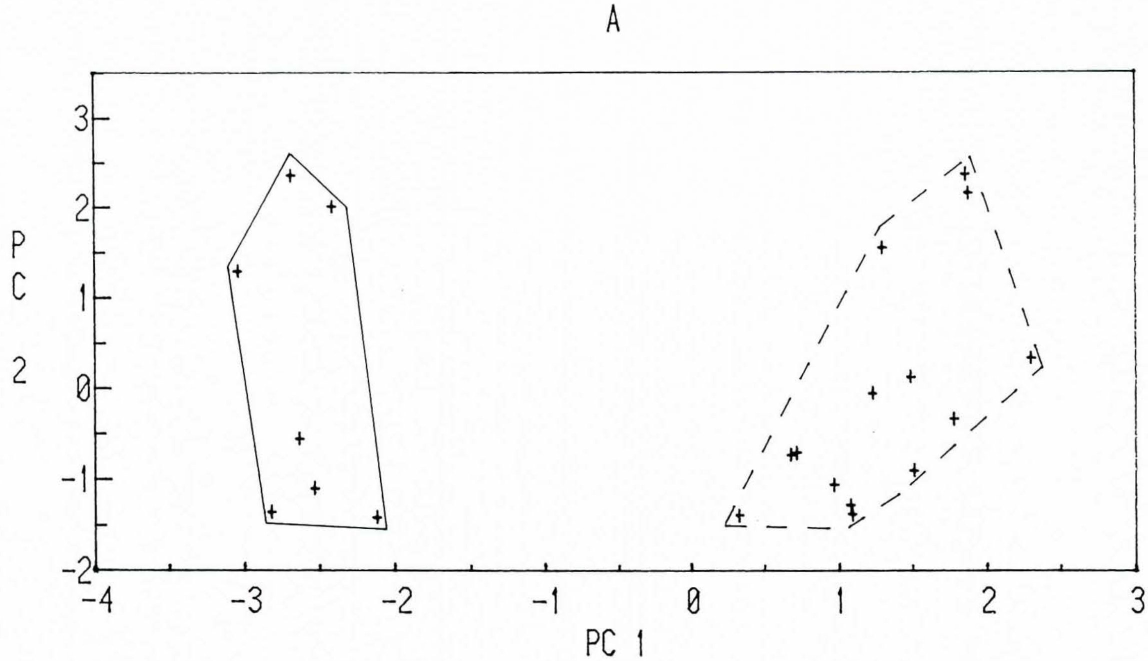


Figure 3A. Results of the first 2 components of PCA for data from the 1981 study showing a fairly tight clustering of the sample sites, with wooded areas (enclosed by the solid line) to the left of the graph, and open areas (enclosed by the dashed line) to the right.



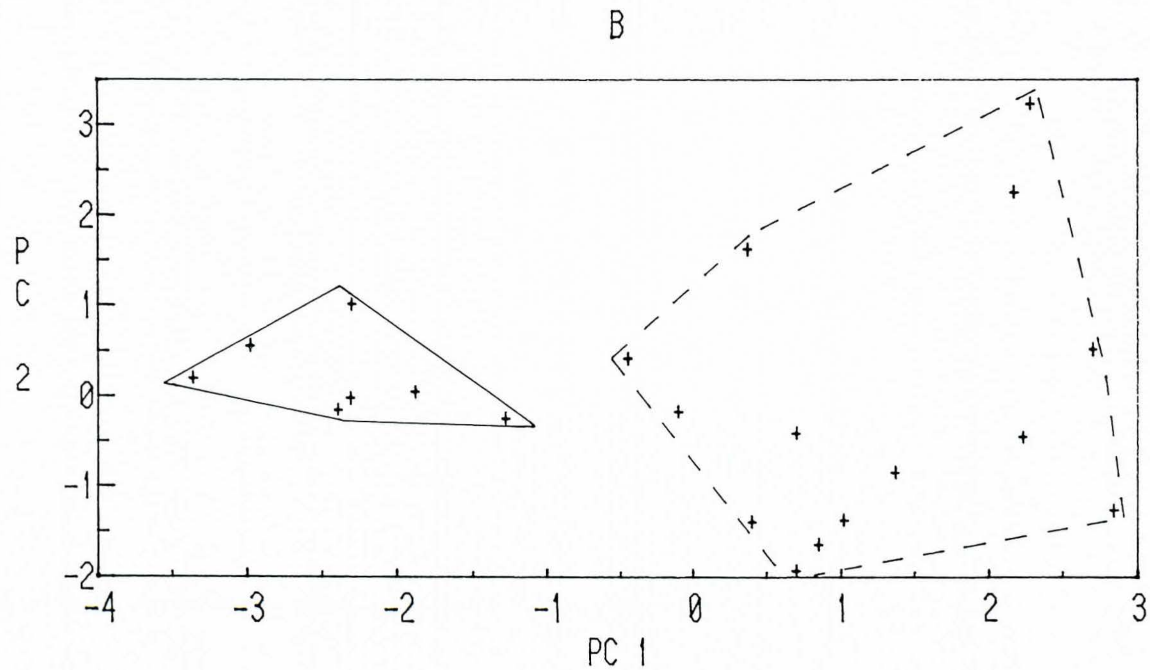




Figure 3B. Results of the first 2 components of PCA for data from the 1981 study (two different components) showing a less distinct differentiation of the wooded (enclosed by the solid line) versus open (enclosed by the dashed line) sample sites, with the sites distributed left-right as above.

Figure 4. The results of PCA on 6 species from the 1981 study.

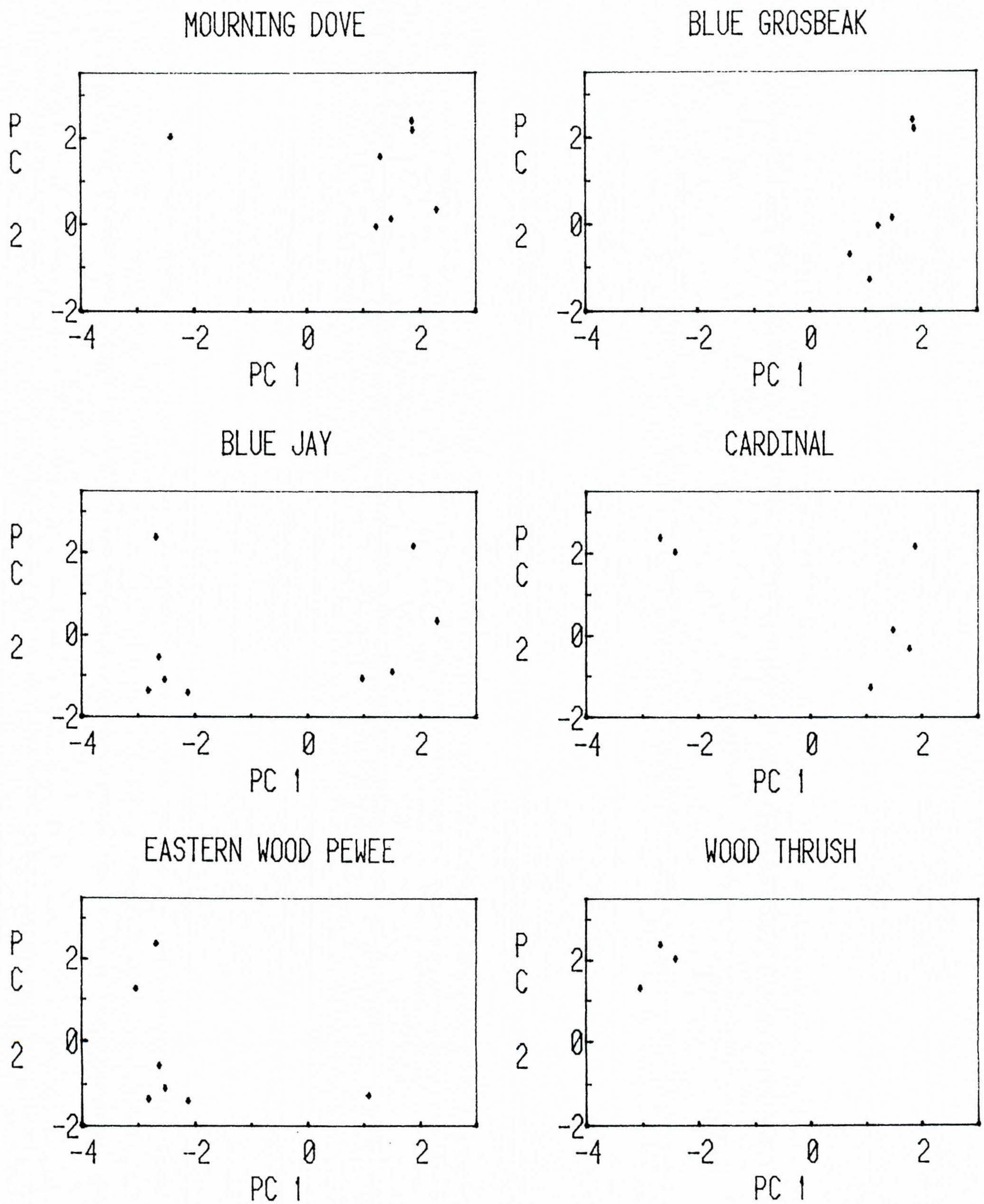


Figure 5. The results of PCA for the AWRA data. 1=Kentucky warbler-selected habitat, 2=ovenbird-selected habitat, and 3=random vegetation sites.

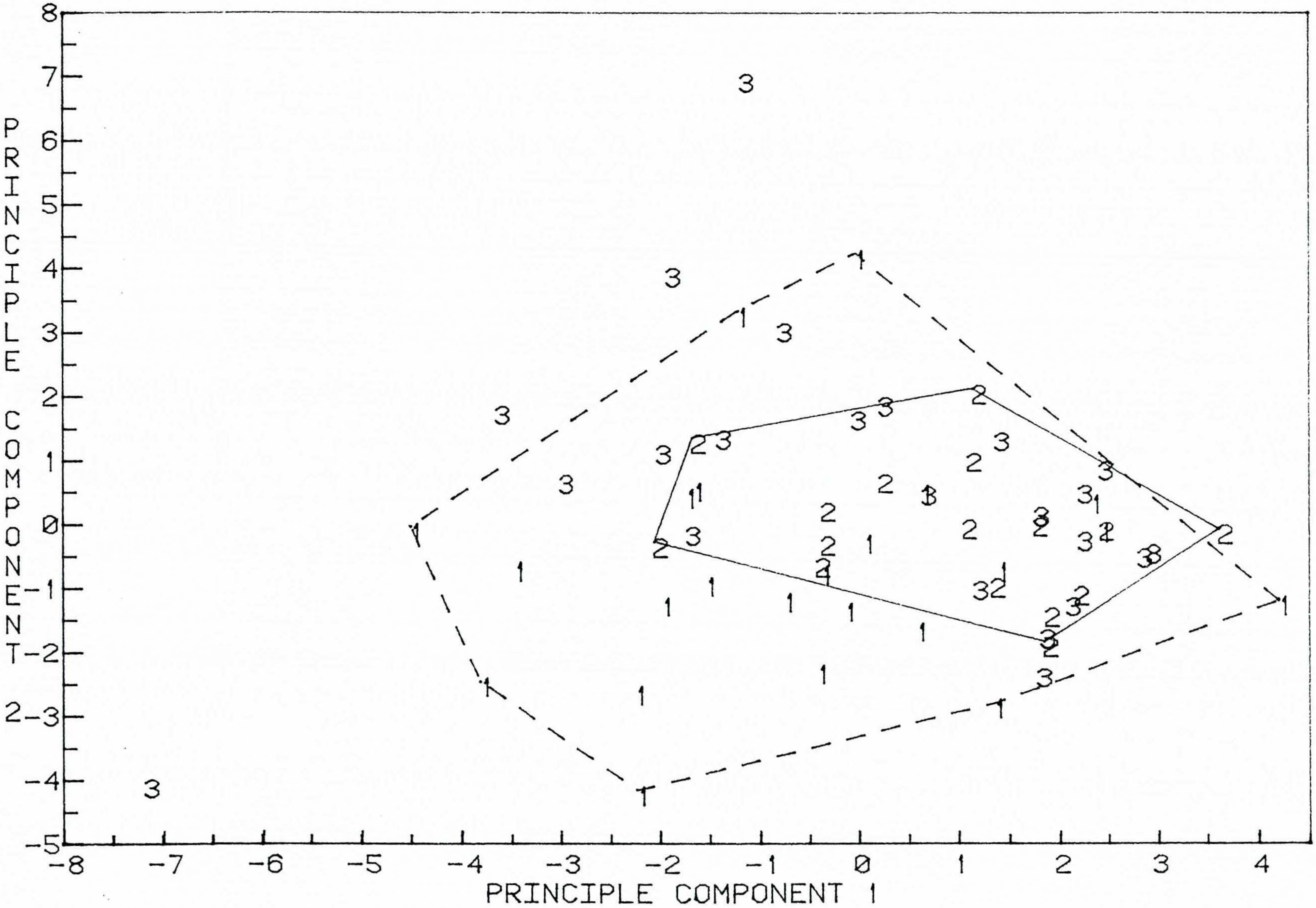


Figure 6. The results of PCA comparing ovenbird- and Kentucky warbler-selected habitat with random vegetation sites. 1=Kentucky warbler-selected habitat, 2=ovenbird-selected habitat, and 3=random vegetation sites.

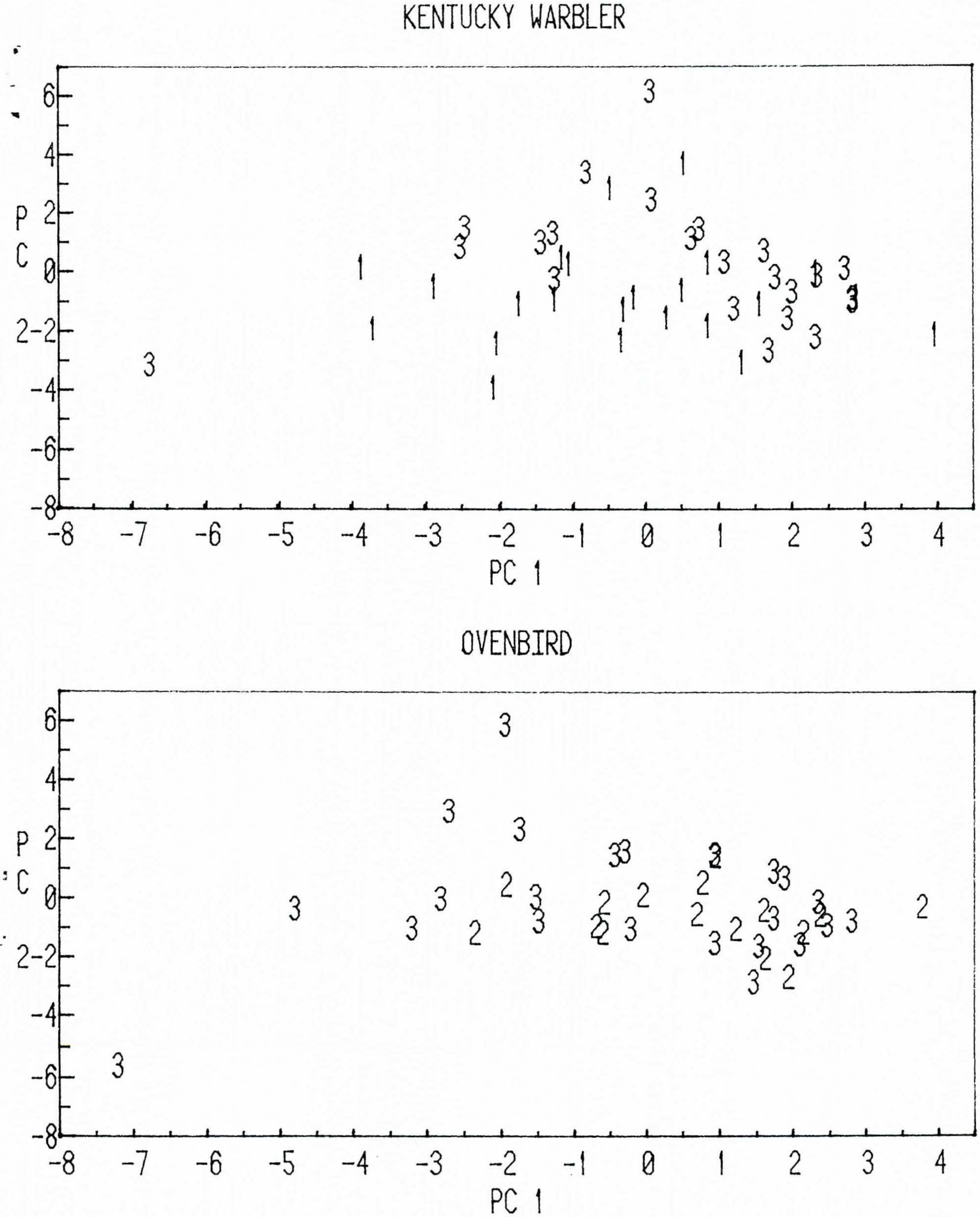


Figure 7. The results of PCA comparing ovenbird- and Kentucky warbler-selected nest sites with random vegetation sites. 1=Kentucky warbler-selected sites, 2=ovenbird-selected sites, and 3=random vegetation sites.

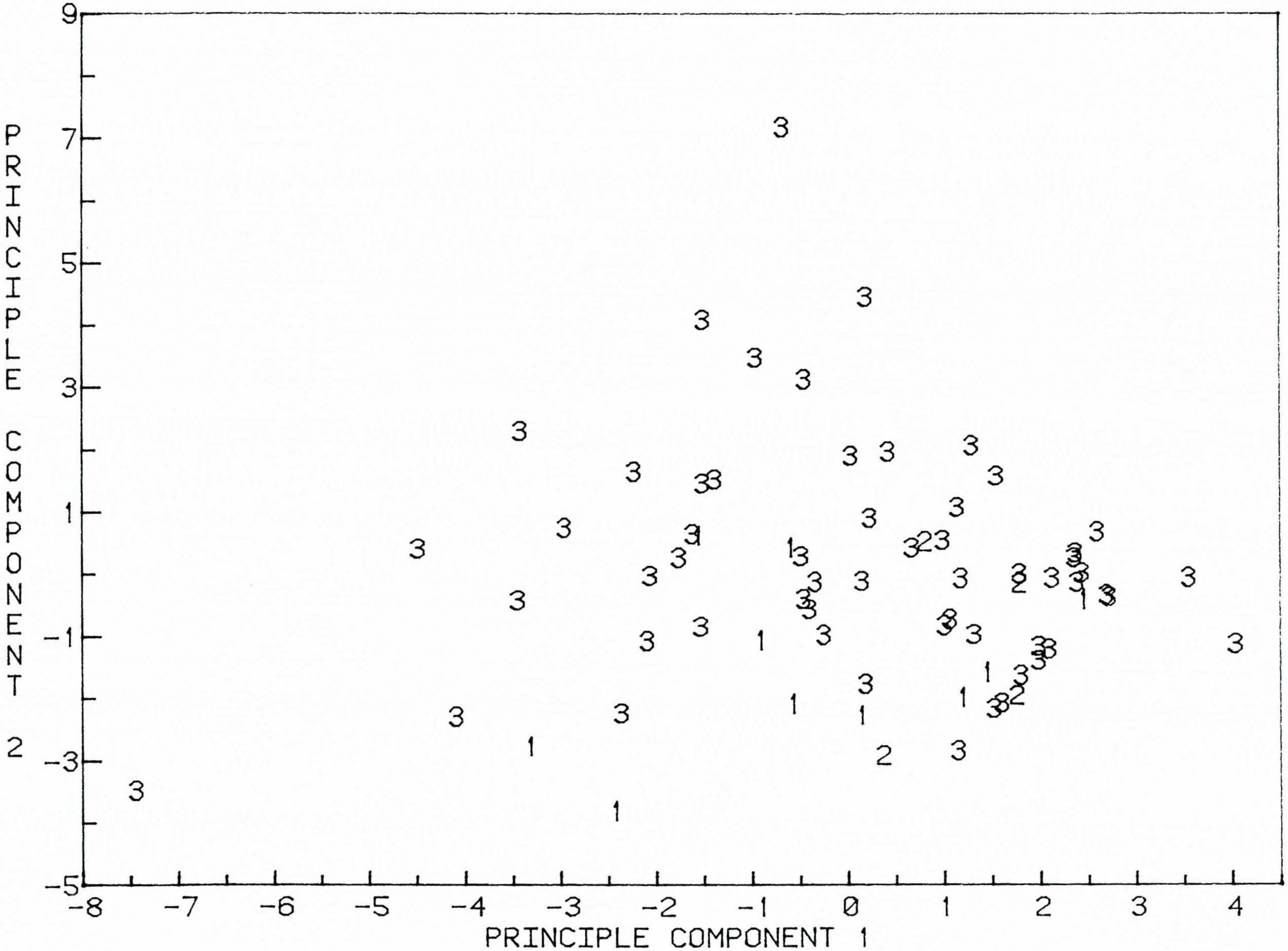


Table 1. The results of breeding bird census on the AWRA for ovenbird and Kentucky warbler during Summer 1984.

| | OVENBIRD | | KENTUCKY WARBLER | |
|---|---|---|---|---|
| Compartment | Territories | Nests | Territories | Nests |
| 1 | 5 | 1 | 6 | 3 |
| 2 | 10 | 0 | 5 | 2 |
| 3 | 13 | 2 | 10 | 2 |
| 4 | 6 | - | 6 | - |
| 5 | 2 | 1 | 7 | - |
| Totals | 36 | 4 | 34 | 10 |

Table 2. Vegetation sampling done within territories, at nest sites, and at random points on the AWRA, Summer 1984.

| Sample Type | No. of Territories | NUMBER OF SAMPLES Within Territory | At Nest | Random |
|---|---|---|---|---|
| Ovenbird | 16 | 75 | 4 | N/A |
| Kentucky warbler | 23 | 91 | 10 | N/A |
| Random | N/A | N/A | N/A | 43 |
| Totals | 39 | 166 | 14 | 43 |

Table 3. Two sets of variables from the 1981 study that were derived using average-linkage cluster analysis as indicated for use in principle component analysis.

Data Set A

| Habitat Characteristics | |
|---|---|
| Mean Percent Canopy Closure | MCAN |
| Mean Percent Ground Cover | MGRD |
| Mean Percent Litter Cover | MLIT |
| Mean Basal Area of Dead Trees | BASDED |
| Mean Small Woody Stems | MSMWOOD |
| Size of Sample Site | SIZE2 |
| Number of Draws on Sample Site | DRAW2 |
| Number of Acres of Crops | CROP2 |
| Number of Meters of Shrub/Tree Fenceline | STFENCE |

Data Set B

| Habitat Characteristics | |
|---|---|
| Mean Ground Cover Height | MGH |
| Mean Litter Depth | MLH |
| Mean Number of Class 1 Live Trees | MLIVE1 |
| Mean Basal Area of Live Trees | BASLIV |
| Mean Number of Class 4 Dead Trees | MDEAD4 |
| Size of Sample Site | SIZE2 |
| Number of Acres of Annuals | ANNUAL2 |
| Number of Meters of Grass/Shrub Fenceline | GSFENCE |
| Number of Ponds on the Sample Site | PONDS2 |

Table 4. Results of principle component analysis of the two sets of variables from the 1981 study.

| Data Set A | | Principle Component I | II |
|---|---|---|---|
| Percent of Total Variance Accounted for | | 49.9 | 21.1 |
| Cumulative Percentage of Total Variance Accounted for | | 49.9 | 63.0 |
| Eigenvectors of Components | | | |
| | MCAN * | -0.44 | 0.26 |
| | MGRD | 0.29 | -0.50 |
| | MLIT | 0.49 | -0.10 |
| | BASDED | -0.36 | -0.03 |
| | MSMWOOD | -0.32 | -0.17 |
| | SIZE2 | 0.21 | 0.57 |
| | DRAW2 | 0.17 | 0.40 |
| | CROP2 | 0.30 | 0.35 |
| | STFENCE | 0.29 | -0.18 |
| **Data Set B** | | **Principle Component I** | **II** |
| Percent of Total Variance Accounted for | | 41.2 | 18.3 |
| Cumulative Percentage of Total Variance Accounted for | | 41.2 | 59.6 |
| Eigenvectors of Components | | | |
| | MGH * | 0.31 | -0.17 |
| | MLH | 0.38 | -0.30 |
| | MLIVE1 | -0.41 | 0.07 |
| | BASLIV | -0.42 | 0.12 |
| | MDEAD4 | -0.34 | 0.06 |
| | SIZE2 | 0.29 | 0.29 |
| | ANNUAL2 | 0.26 | 0.49 |
| | GSFENCE | 0.30 | 0.54 |
| | PONDS2 | 0.22 | -0.49 |

* Variable abbreviations as in Table 3.

Table 5. Results of principle component analysis of the Ashland Wildlife Research Area study of Kentucky warblers and ovenbirds.

| | Principle Component I | II |
|---|---|---|
| Percent of Total Variance Accounted for | 16.4 | 12.2 |
| Cumulative Percentage of Total Variance Accounted for | 16.4 | 28.6 |
| Eigenvectors of Components | | |
| Maximum Canopy Height | 0.31 | 0.01 |
| Slope | 0.12 | -0.03 |
| Percent Canopy Coverage | 0.35 | 0.18 |
| Percent Subcanopy Coverage | 0.34 | 0.02 |
| Percent Ground Cover | -0.31 | -0.27 |
| Mean Ground Cover Height | -0.33 | -0.25 |
| Percent Litter Coverage | 0.01 | 0.18 |
| Mean Litter Depth | 0.24 | -0.04 |
| Class 1 Live Trees | 0.29 | -0.05 |
| Class 2 Live Trees | 0.01 | 0.27 |
| Class 3 Live Trees | -0.11 | 0.40 |
| Class 4 Live Trees | -0.14 | 0.35 |
| Class 5 Live Trees | 0.04 | 0.25 |
| Class 6 Live Trees | 0.20 | -0.08 |
| Class 7 Live Trees | 0.21 | -0.12 |
| Class 8 Live Trees | 0.18 | -0.15 |
| Class 9 Live Trees | 0.16 | -0.03 |
| Class 10 Live Trees | 0.17 | -0.06 |
| Class 1 Dead Trees | 0.02 | 0.31 |
| Class 2 Dead Trees | -0.12 | 0.22 |
| Class 3 Dead Trees | 0.04 | 0.27 |
| Class 4 Dead Trees | 0.08 | 0.22 |
| Class 5 Dead Trees | 0.09 | 0.06 |
| Class 6 Dead Trees | 0.01 | 0.01 |
| Class 7 Dead Trees | 0.12 | -0.06 |
| Class 8 Dead Trees | 0.09 | -0.10 |
| Class 9 Dead Trees | 0.07 | -0.01 |
| Class 10 Dead Trees | -0.08 | 0.03 |
| Number of Woody Stems in 0.01 Acres | 0.18 | -0.20 |

Table 6. Results of principle component analysis for Kentucky warblers and ovenbirds analyzed individually against the randomly selected plots at the Ashland Wildlife Research Area.

| | Kentucky Warblers | | Ovenbirds | |
|---|---|---|---|---|
| | Principle Components | | | |
| | I | II | I | II |
| Percent of Total Variance Accounted for | 15.9 | 12.8 | 18.1 | 11.4 |
| Cumulative Percentage of Total Variance Accounted for | 15.9 | 28.7 | 18.1 | 29.5 |
| Eigenvectors of Components | | | | |
| Maximum Canopy Height | 0.31 | -0.01 | 0.33 | 0.09 |
| Slope | 0.18 | -0.09 | 0.07 | 0.09 |
| Percent Canopy Coverage | 0.37 | 0.13 | 0.31 | 0.21 |
| Percent Subcanopy Coverage | 0.35 | -0.02 | 0.35 | 0.10 |
| Percent Ground Cover | -0.34 | -0.23 | -0.25 | -0.31 |
| Mean Ground Cover Height | -0.36 | -0.20 | -0.28 | -0.29 |
| Percent Litter Coverage | -0.01 | 0.19 | -0.03 | 0.18 |
| Mean Litter Depth | 0.22 | -0.05 | 0.27 | -0.01 |
| Class 1 Live Trees | 0.29 | -0.10 | 0.28 | -0.01 |
| Class 2 Live Trees | 0.06 | 0.26 | -0.10 | 0.19 |
| Class 3 Live Trees | -0.30 | 0.40 | -0.20 | 0.41 |
| Class 4 Live Trees | -0.06 | 0.35 | -0.22 | 0.25 |
| Class 5 Live Trees | 0.07 | 0.23 | -0.03 | 0.26 |
| Class 6 Live Trees | 0.16 | -0.10 | 0.22 | -0.12 |
| Class 7 Live Trees | 0.21 | -0.13 | 0.18 | -0.22 |
| Class 8 Live Trees | 0.17 | -0.17 | 0.15 | -0.22 |
| Class 9 Live Trees | 0.16 | -0.08 | 0.10 | 0.03 |
| Class 10 Live Trees | 0.13 | -0.09 | 0.15 | -0.06 |
| Class 1 Dead Trees | 0.08 | 0.31 | -0.01 | 0.32 |
| Class 2 Dead Trees | -0.08 | 0.23 | -0.10 | 0.21 |
| Class 3 Dead Trees | 0.04 | 0.27 | 0.05 | 0.23 |
| Class 4 Dead Trees | 0.08 | 0.22 | 0.11 | 0.20 |
| Class 5 Dead Trees | 0.02 | 0.07 | 0.15 | -0.02 |
| Class 6 Dead Trees | -0.01 | 0.03 | 0.01 | -0.05 |
| Class 7 Dead Trees | 0.12 | -0.04 | 0.08 | -0.14 |
| Class 8 Dead Trees | 0.10 | -0.13 | 0.12 | -0.08 |
| Class 9 Dead Trees | 0.09 | -0.02 | 0.02 | -0.01 |
| Class 10 Dead Trees | -0.09 | 0.04 | -0.10 | -0.04 |
| Number of Woody Stems in 0.01 Acres | 0.18 | -0.25 | 0.26 | -0.05 |

Table 7. Results of logistic regression analysis for six selected species from the 1981 study.

| Species | Model P | A | B(Variable) | Variable P |
|---|---|---|---|---|
| Mourning Dove | <0.0001 | -8.14 | 0.25(SIZE2) | 0.0165 |
| | 0.0016 | -1.87 | 0.25(CROP2) | 0.0179 |
| Blue Grosbeak | 0.0146 | -2.22 | 0.32(MLH) | 0.0359 |
| Blue Jay | 0.0076 | 2.20 | -0.06(MGRASS) | 0.0290 |
| Cardinal | 0.0418 | -3.15 | 0.08(SIZE2) | 0.0712 |
| Eastern Wood Pewee | 0.0003 | 1.71 | -0.22(MLIT) | 0.0041 |
| Wood Thrush | -- | -- | --* | -- |

* MLIVE3 and MDEAD2 had strong individual values (P<0.0001) to be included, however, procedural problems in the calculation of the Beta (B) values failed to generate adequate estimates.

Table 8. Results of logistic regression analysis for Kentucky warbler, ovenbird, and their respective nest locations from the Ashland Wildlife Research Area study.

| | Model P | A | B(Variable) | Variable P |
|---|---|---|---|---|
| Kentucky Warbler | 0.0005 | −10.05 | 0.07(MGRDCV) | 0.0028 |
| | | | +0.07(MWDYS) | 0.0323 |
| | | | +1.59(MMLTRDP) | 0.0475 |
| | | | +0.19(MCL3) | 0.0977 |
| Ovenbird | 0.0004 | −7.42 | 2.86(MMLTRDP) | 0.0034 |
| Kentucky Warbler Nests | 0.0008 | −10.39 | 0.07(MGRDCV) | 0.0048 |
| | | | +0.22(MXCANHT) | 0.0433 |
| Ovenbird Nests | 0.0031 | −4.61 | 3.18(MCD5) | 0.0158 |

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